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TECHNOLOGY UTILIZATION

WELDING TECHNOLOGY

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technical developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This publication is part of a series intended to provide such technical information. It describes a variety of innovations in the technique of joining metals with a degree of efficiency adequate to contain gases at high pressures or fluids throughout a wide temperature range. It also describes means for the handling of difficult weld configurations (circular, concentric, right-angled, etc.). Even those tubes previously considered almost inaccessible can be welded with little or no risk of distortion, as can large surfaces of varying thickness. Simultaneous welding techniques also have added to the ever-widening scope of metallurgical fabrication.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader's Service Card included in this compilation.

Unless otherwise stated, NASA contemplates no patent action on the technology described.

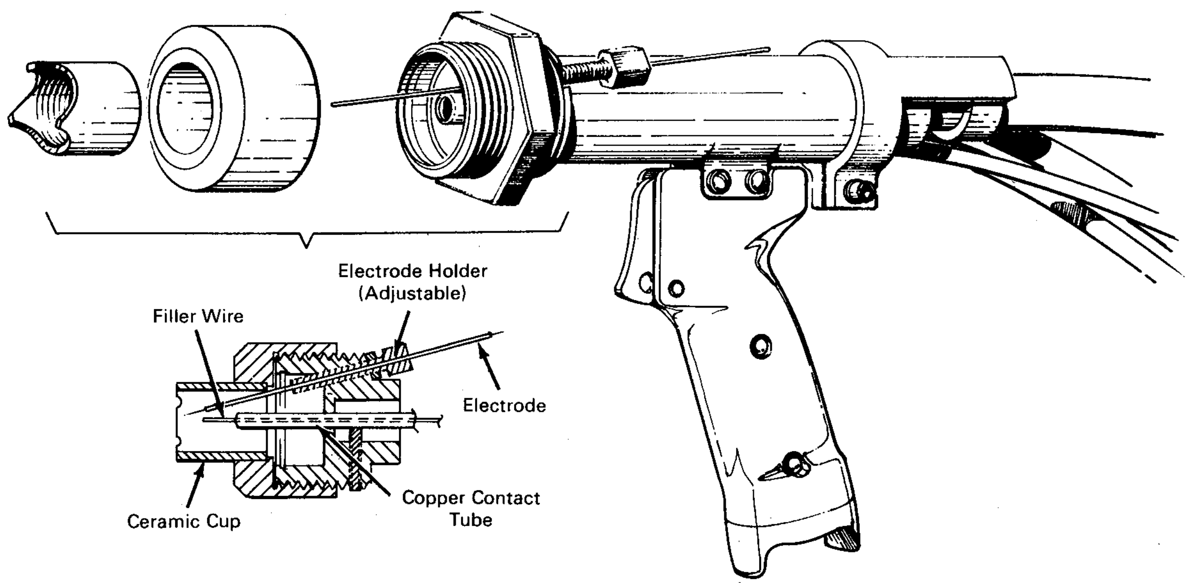
We appreciate comments by readers and welcome hearing about the relevance and utility of the information in this compilation.

Ronald J. Philips, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

Contents

Section 1. Welding with Inert Gas

HYBRID GAS-TUNGSTEN ARC, GAS METAL ARC SPOT WELDING TORCH



The general purpose of this innovation is to enable a dual-welding hybrid torch (see fig.) to be used in a single spot weld. Commercially available spot welding torches have been designed for either gas-tungsten arc (GTA) or gas metal arc (GMA) use, but not for both simultaneously.

While experimental work has not yet been completed, the idea is considered a substantial advance in the art and should stimulate further research since it combines the advantages of GTA and GMA welding. Specifically, while GTA welding is frequently used in production applications where high travel speeds are important, GMA welds can be made faster and more economically when dealing with thicknesses above 1/4 inch.

The following improvements may be noted as deriving from both processes: (1) elimination of difficulties associated with feeding wire under the electrode (GTA); (2) minimized electrode inclusion in the puddle; (3) penetration of the interface (achieved by the gouging action of the filler wire used in the GMA phase), driving out contamination and producing a cleaner weld; (4) elimination of erratic and explosive arc initiation (common with GMA welds) means more accurate weld timing; and (5) slow initial heating (GTA upslope) and slow cooling (GTA downslope), which minimize shrinkage cracks at the interface.

Essentially, the device functions as follows: The torch is connected to the welding power in the normal manner; high frequency current initiates the arc between the work and the tungsten electrode; current is programmed for gradual upslope to the weld value. During this period, the GTA mode of operation is maintained between electrode and work (with no wire feed). When weld current is reached, wire feed is initiated. The arc transfers effectively to the wire as the latter passes the tungsten electrode tip. The process is now in the GMA mode. As the weld ends, the wire feed is stopped and the current downslope initiated. During this downslope phase, the arc transfers back to the tungsten and the weld is completed in the GTA mode.

Believed new are the inclusion of both electrode and wire guide in the same welding torch, and the slow, controlled heating with deep gouging during the weld cycle for proper penetration and clean work. This torch was designed to produce quality spotwelds and should prove valuable for any task requiring welding of a thin to a thick sheet.

Source: L. E. Nordholt, G. E. Cook, and W. M. McCampbell of Merrick Engineering, Inc. under contract to Marshall Space Flight Center (MFS-20078)

Circle 1 on Reader's Service Card.

OXYGEN-INERT GAS SHIELDING FOR ARC STABILIZATION

Welding Conditions and Non-Destructive Test Results from Butt Welds in ⅛-inch 2014-T6 Aluminum Alloy

Machine Combination: Linde Missile Maker
Linde OM-48 Side Beam and Carriage
Linde St-5 Torch, No. 10 (⅝-in. I.D.) Nozzle

Fixture: Simulated Meridian Weld
Filler Alloy: 3/64-in. Dia. 4043 (Linde Hq)
Joint: Square Butt, Single Pass
Torch Angle: 15° Lead

Weld No.	Shielding Gas Flow	Current amp.	Voltage (v)	Weld Speed (ipm)	Bead Width (in.)	Inspection Results		
						Visual	Dye-Penetrant	X-Ray
19	Argon 60 (cfh)	140	23	26	.359	No Defects	Very Slight Surface Porosity	Slight Scattered Porosity
20	Argon 60 (cfh) Argon-Oxygen (O_2-1) 6 (cfh)	140	22.5	26	.313	No Defects	No Indications	Clear

Following a detailed study of gas mixtures, research conclusively proved that an addition of 0.1% oxygen to an inert gas such as argon improved the arc stability of metal inert-gas (MIG) welding of aluminum, produced a narrower weld, and minimized formation of surface and internal porosity. No harmful effects were noted. The mechanical and stress corrosion properties of the weld remained unaffected.

Formerly, recurring problems in MIG welding, particularly of aluminum alloys, have been arc instability and porosity formation. Elimination of these problems has been difficult. It was presumed that oxygen would be harmful to aluminum welds, because it was likely to produce oxide inclusions, but oxygen additions to the shielding gas have long proved useful in improving arc stability and minimizing porosity in steel welding.

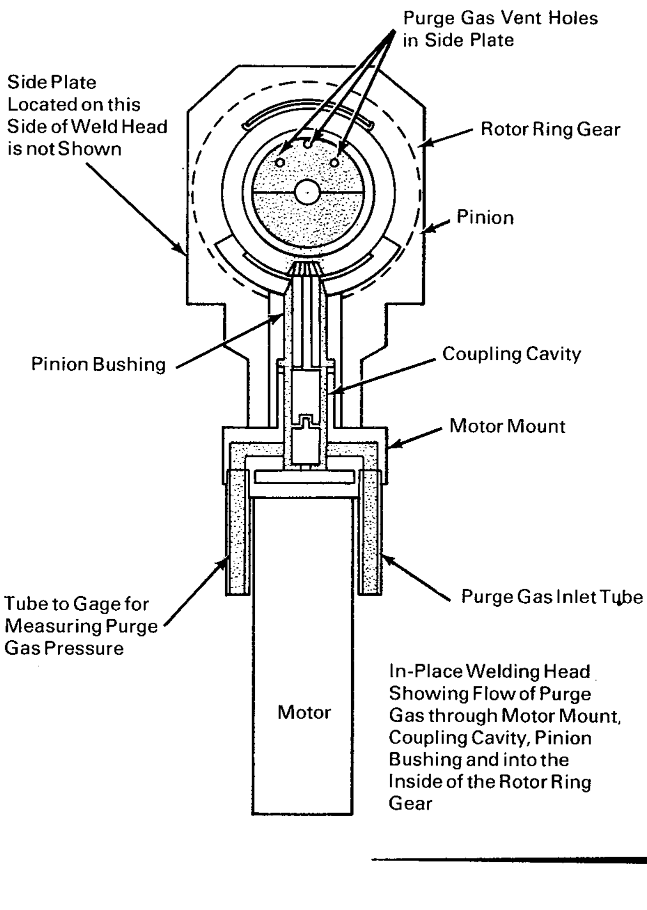
These gas mixtures have since been used in production fabrication and have successfully passed nondestructive tests (see Table). They should now find increasing use outside the aerospace industry in the fabrication of tanks and the joining of materials.

Source: Robert S. Wroth and John Hargering of McDonnell Douglas Corp. under contract to Marshall Space Flight Center (MFS-13394)

Circle 2 on Reader's Service Card.

IMPROVED PURGE GAS SUPPLY FOR IN-PLACE WELDING HEAD

The subject innovation provides a complete purge for any surface to be welded—a matter of prime importance for quality work. Some major problems have been solved as a result.



In-Place Welding Head Showing Flow of Purge Gas through Motor Mount, Coupling Cavity, Pinion Bushing and into the Inside of the Rotor Ring Gear

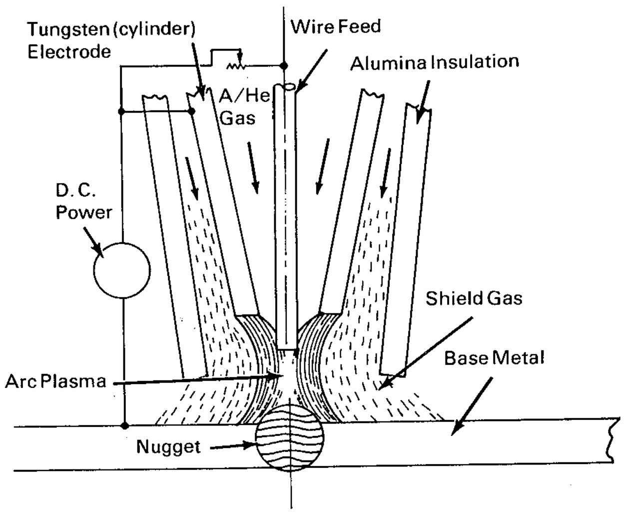
Formerly, purge gas was introduced into the welding head through a side-mounted tube. This caused a variety of manufacturing problems, some of them serious, including body cracking and protrusion. Head assembly design for welding in close quarters also proved difficult.

Rerouting the purge gas flow through the motor mount, the coupling cavity, the pinion bushing and the interior of the rotor ring gear (see fig.) solved the difficulty. Principal modification was made by machining the welding head to accept two 3/16-inch outside diameter stainless steel tubes, one for providing purge gas, the other for measuring gas pressure in the motor mount coupling cavity. The pinion bearing also was modified by means of four slots, allowing purge gas to flow from the coupling cavity to the weld head of the body, directly into another cavity formed by the motor ring gear and welding sleeve. A further advantage is the applicability of this method to any existing in-place tube welding head of similar design.

Source: E. J. R. Lang of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18083)

No further documentation is available.

MIG/TIG WELDER



Two proven processes have been combined by a relatively simple means to improve the quality of welds. This technique is applicable to countless industrial purposes.

Both tungsten-inert gas (TIG) and metal inert gas (MIG) welding torches suffer from limited efficiency. TIG welding torches use a side wire feed and centered tungsten electrode. The MIG system features a current carrying wire feed through the center of the torch. However, combining the processes so that the wire passes through the center of a cylindrical tungsten electrode produces a higher flux density, deposition rate, and efficiency.

First, the current is passed through tungsten to establish arc. Gas (standard argon/helium mix) is then routed through the inside of the tungsten cylinder to form a plasma. The wire is moved into the plasma as in the MIG process (see fig.). The combined current density melts the feed wire rapidly while providing intense heat flux at the workpiece.

Source: Harry D. MacNary of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-13179)

No further documentation is available.

MODIFIED IN-PLACE WELDING HEAD PROVIDES IMPROVED INERT-GAS PURGE

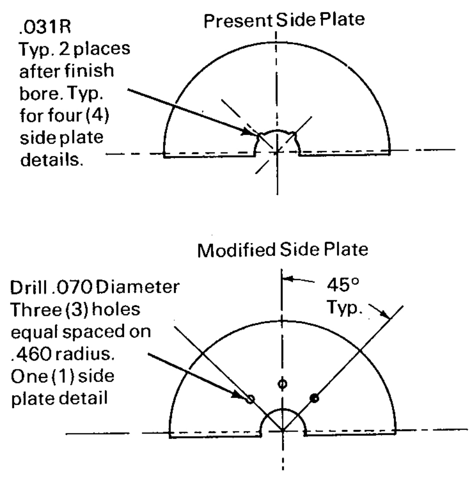
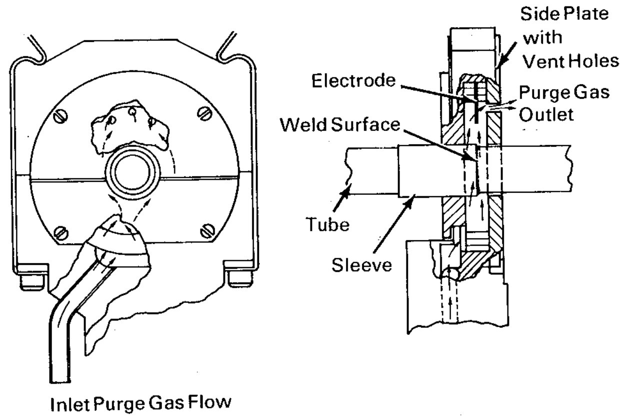


Figure 1.



Typical In-Place Weld Head Assembly Showing How Purge Gas Completely Blankets the Weld Surface

Figure 2.

A means has been found of introducing purge gas directly into the cavity surrounding a weld area. This has overcome a major problem encountered in the past—that of supplying inert gas over the actual surface to be welded. One solution was to add small holes, grooves and slots machined into side plates in the welding head rotor. This allowed the purge gas to enter the cavity around the sleeve to be welded, but the method also gave rise to several problems. There was the cost of rotor machining and of coating the inside surface of the rotor with resin. Also, side plate slots (a major cause of side plate breakage) had to be machined. Further, there was a fluctuation in purge flow and an incomplete purge of the cavity.

The present improvement was realized by replacing the two grooves with three holes drilled opposite the entry point on the side plates (Fig. 1). The purge gas could then completely fill the cavity (Fig. 2) and provide an inert blanket over the entire weld area. Further economy was achieved by using thermo-setting glass-cloth tape as a substitute for the resin previously used in coating the interior surface of the rotor.

Source: E. J. R. Lang of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14337)

Circle 3 on Reader's Service Card.

AUTOMATIC TUNGSTEN-INERT GAS WELDING OF ALUMINUM FITTINGS IN ALUMINUM STRUCTURES

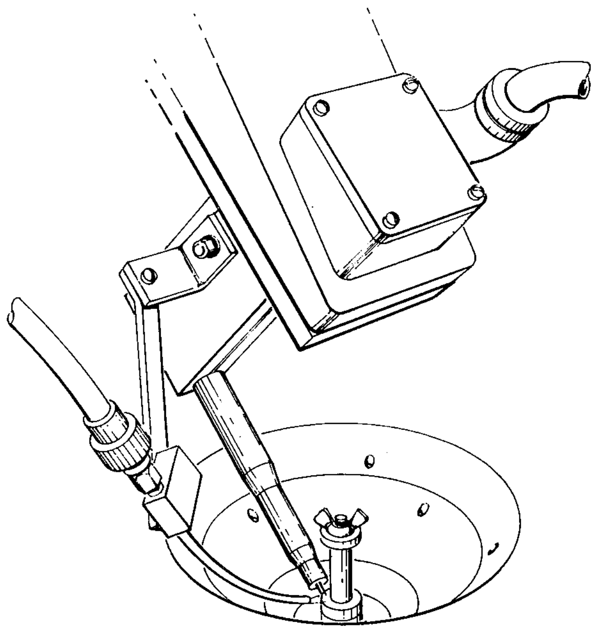


Figure 1.

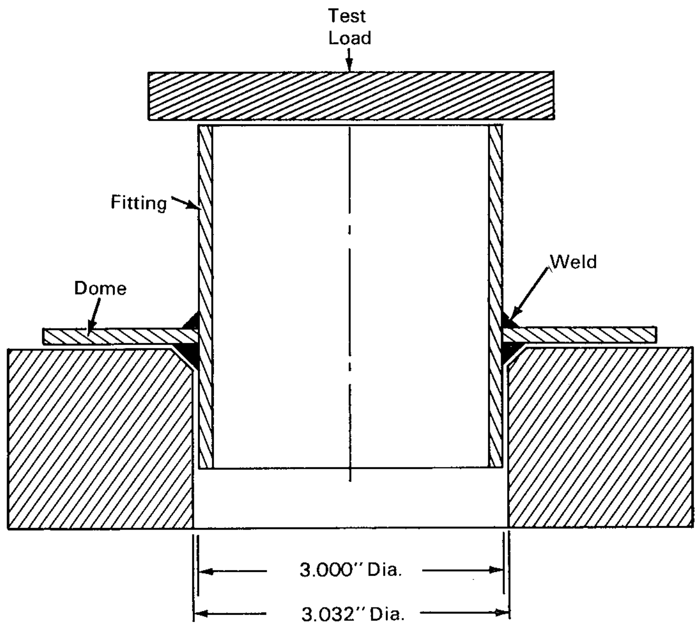


Figure 2. Section of Test Shear Fixture and Simulated Fitting-To-Dome Weld Sample

The use of automatic tungsten-inert gas (TIG) welding as a certified process for installing aluminum fittings in aluminum structures, such as the domes of cryogenic tanks, represents an important innovation. The elimination of manual positioning of the torch makes a tighter control of weld parameters possible. This method has also proved especially helpful in programming starts, overlaps and tie-off areas and eliminating crater cracking.

The application of this process has upgraded weld quality and minimized the need for manual repair welding.

In the past, the work was accomplished by manual metal inert gas (MIG) welding. Poor weld quality resulted, largely because of operator problems in manipulating the torch around small fittings. Multiple repairs which degraded weld mechanical properties were almost universally required to correct porosity and cracking problems.

Industrially, the dc TIG process for welding of fittings to domes can be of significant use. While this type of welding is highly specialized, its commercial superiority over the manual MIG weld of fittings to domes is evident.

Figure 1 shows a closeup of a one-inch diameter fitting and a dome of 0.113-inch thickness positioned for welding the fixture. In these tests to determine machine settings applicable to production fabrication, double fillet welds were prepared in several sizes of fittings, using domes with a thickness of 0.113 to 0.190 inch. Tests also were conducted on production prototype parts to establish procedures for starting, overlapping, and stopping welds. A satisfactory technique which produced no defects in start and stop areas resulted from these tests.

Shear test welds (Fig. 2) were performed solely for the purpose of obtaining representative mechanical property information. Certification of the TIG process for welding aluminum fittings to domes was based on the study of metallurgical sections subjected to visual, dye penetrant, and X-ray inspections, rather than mechanical testing.

Perhaps the most critical factor in automatic TIG welding, especially in fillet joints, is the alignment of the electrode and filler rod with respect to the joint. In the production fixture, available space at the point of arc and wire contact was so limited that the wire feed mechanism provided by the equipment manufacturer could not be used. The wire feed head was therefore relocated and an outlet guide designed that would fit into the confined area. These modifications resulted in satisfactory arc and wire feed operation.

Source: Robert S. Wroth of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-12316)

Circle 4 on Reader's Service Card.

Section 2. Precision Welding

PRECISION EIGHT-AXIS WELDING TORCH POSITIONER

A universal welding torch holder and positioner has been fabricated, providing eight possible axes of motion, each independent of the other. Any desired weld head position and attitude may be made in relation to a component fixture for welding.

There are no commercially available multi-axis positioners that can provide the flexibility and precision of positioning obtainable with the present unit. This new design therefore represents a significant improvement that should appeal to all job shops and manufacturers engaged in the precise welding of varied medical and laboratory equipment.

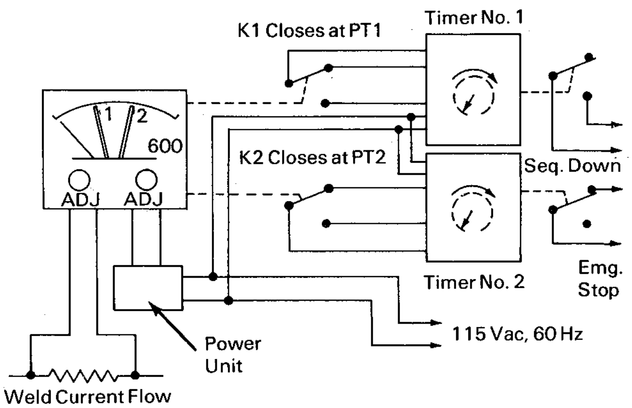
The final location of the weld torch is obtained by viewing through a 20X microscope with a micrometer eyepiece. The microscope is bracket-mounted to the torch holder, thereby moving it with the torch and permitting electrode-to-joint alignment and gap control. The positioner has a movable base in one axis of the horizontal plane. The arm moves up and down and rotates about the column in the same way as a radial arm drill press. An X-Y-Z three-axis slide is mounted in a tilting yoke which is part of a swiveling head located on the end face of the arm.

Source: A. Markel of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-91180)

No further documentation is available.

AUTOMATIC DC ARC WELD MACHINE

This disclosure relates to an over-current sensing circuit which includes an ammeter with two adjustable positions. The first position limits the current to a normal operating condition. The second position is in effect an emergency stop command which activates a shutdown sequence.



The foregoing offers an important step forward in constant-current dc arc welding machines. It is also a useful addition to welding machines not presently equipped with current-limiting systems, and is applicable to all electrical machinery where costly damage might result from a control malfunction. This device should also prove particularly useful in the aircraft, aerospace and electrical machinery fields.

The meter relay switching outputs actuate a sequence-down and/or emergency-stop variable-delay relay. The timers are adjustable from 0.5 to 3 seconds and are installed to allow a current amplitude combination to be selected for carrying out the weld machine command.

Should the pointer reach PT. 1 (see fig.), timer #1 begins and sends a sequence down (SEQ. DOWN) command if the pointer remains at PT. 1 beyond a preset time limit. Timer #2 functions in the same way for PT. 2 but sends an emergency stop (EMG STOP) command. Points 1 and 2 are adjustable on the meter. Timers 1 and 2 are adjustable on the front of the panel.

Source: James R. Bigham of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-16614)

Circle 5 on Reader's Service Card.

MANUAL WELDING TORCH WITH AUTOMATIC ARC LENGTH CONTROL

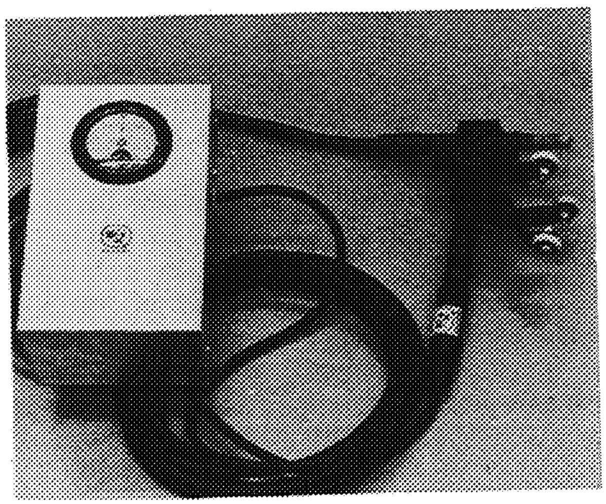


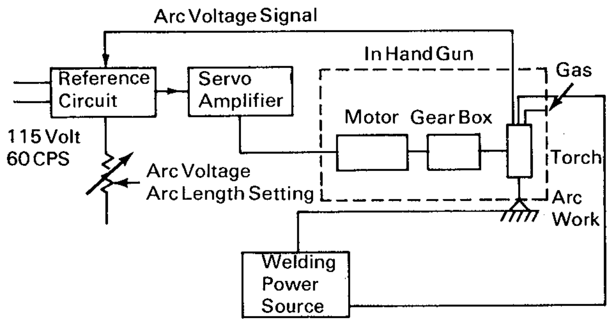
Figure 1

A hand welding torch is now available that allows manual manipulation while automatically controlling arc length. This precise control produces a uniform weld joint. One of the critical parameters which must, however, be held to close tolerance is the distance between the electrode and weld puddle (arc length).

The application offers considerable promise in the broad industrial area of field work wherever manual tungsten-inert gas welding (TIG) is in use.

Automatic control of arc length is here achieved by a motor in the hand gun which repositions the arc length to a "dial-in" voltage to compensate for changes in length due to the welder's hand motion.

The arc length control equipment for a 100% hand welding operation (Fig. 1) is easily used and requires a less experienced operator than the conventional manual welder. It is readily adaptable and can be used with weld torches of varying sizes. Further, because of the equipment's accuracy, arc length is kept to within 0.005 inch over irregular



Block Diagram
For Automatic Arc Length Control
(Hand Welding)

Figure 2

surfaces. The arc length is automatically maintained by a motorized controller using a preset voltage. The controller is activated by a signal picked up from the torch (Fig. 2) and passed through the voltage starter. This is believed to be a unique innovation for a hand welding torch.

The callouts in Figure 2 show how the torch is connected to the gun, which includes a motor and gearbox. The arc voltage signal is connected to one side of the reference circuit where the arc voltage setting is compared to the arc voltage signal. Before the two signals become equal, an output signal is obtained from the reference circuit and applied to the servo amplifier to drive the motor, which positions the tungsten-to-work distance (arc length) until the arc voltage signal is equal to the arc voltage setting. Given this condition, the reference output is zero and the servo amplifier does not drive the motor. Only if the operator inadvertently moves the torch-to-work distance does the motor control reposition the torch to the former arc length.

Power requirement for the dc arc welder power supply is 115 volts, 60 cycles per second.

Source: W. F. Iceland of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-11851)

No further documentation is available.

EQUIPMENT AND METHODS USED FOR AUTOMATIC BUTT WELDING OF TUBE ASSEMBLIES

A complete system has been designed and developed to produce Class I butt welds with automatic equipment. The innovation has virtually overcome all problems formerly encountered in this kind of work and offers important benefits to any private enterprise facility engaged in work on pneumatic tubing systems, whether on the bench or in field installations.

Improvements with this technique include a variable arc length; the ability to provide inserts where tubes are of similar outside diameter but have differing wall thicknesses; and freedom from offset limitation between the insert center line and the center line of the weld head electrode. Prior to these improvements, more time was frequently needed to complete an efficient tube assembly butt weld.

In effect, the innovation here described is a complete system in itself which includes the following major elements: (a) a modified control purge panel, precisely regulating the required preset purge gas differential pressure between the inside of the weld head and that of the tube; (b) a consumable insert positioned on the outside diameter of the tube, which takes advantage of the close tolerance to which the inside diameter of the tubing is manufactured; (c) tooling jigs that make it possible for the first time to automatically butt-weld special machined flare fittings; and (d) a schedule giving all machine, welding head, and purge panel parameters for the different diameter tubes to be welded.

The foregoing benefits can be obtained with the use of the existing automatic weld heads and program welding machines that are used for melt-through welding. This takes advantage of the welder's familiarity with such equipment to minimize the training time required for learning to use this new welding system.

Source: E. J. R. Lang and
Bruch Van H. Wagner of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18525)

Circle 6 on Reader's Service Card.

SIMULTANEOUS OUT-OF-POSITION WELDING

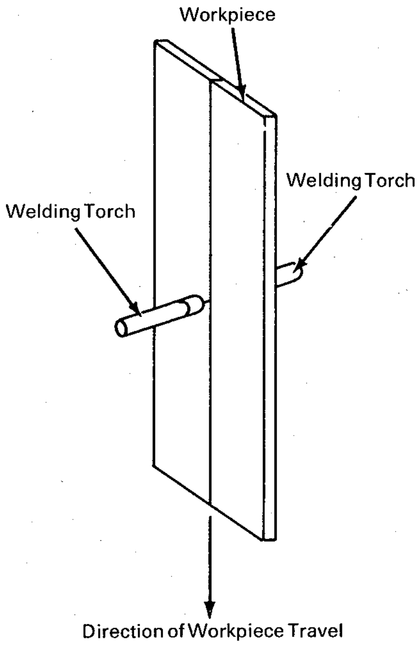


Figure 1. Cross Section of Tooling and Weld Joint

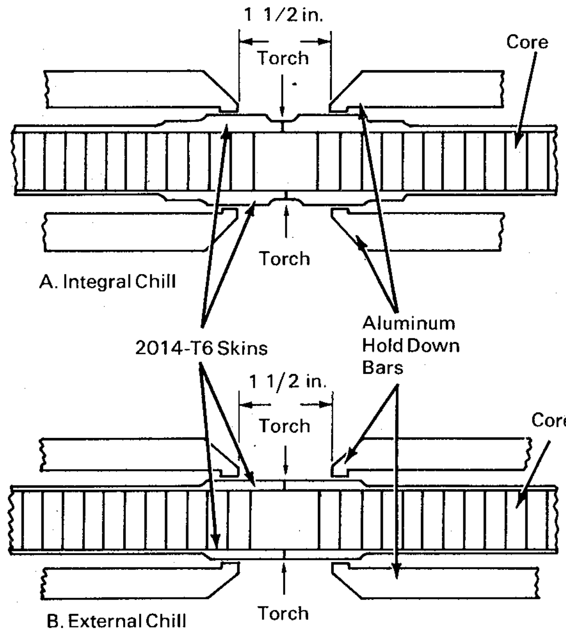


Figure 2. Tooling and Weld Joints for Sandwich Panel

A simultaneous welding technique used as shown in Figure 1, applicable both to metal mixed inert gas (MIG) and tungsten-inert gas (TIG) processes, should prove most useful to industries concerned with welding honeycomb structures.

The advantages of this process, intended for welding sandwich segments, are (1) minimized distortion and residual stresses and (2) higher weld elongation properties (thermal cycles for bonding are performed before welding).

In addition, the advantages of the process of welding single joints are (1) more symmetrical weld, (2) high welding rates with fewer weld passes, and (3) simplicity. Initial tests were carried out with a modified fusion welder and performed on integral chill panels (Fig.2A) after establishing machine settings on a flat plate. A dozen welded panels were prepared for mechanical testing and nondestructive inspection. A cross-section sketch of the tooling and weld joint is shown in Figure 2.

Specimens from the welded panels have been tested for tension and compression. Photo macrographs of several welds were subsequently prepared for analysis. Testing included both welded and repaired specimens of each configuration.

A limited number of X-ray tests (three radiographs to each welded test panel) also were performed, using a technique which involved positioning the film against the penetration bead by means of a form strip and allowing an exposure of four minutes. Essentially, the quality of the X-ray images equalled that currently used on bulkheads subjected to searching stresses. It therefore justified the continuance of tests with this technique.

Source: John Haryung, Francis L. Kinley, and Robert S. Wroth of McDonnell Douglas Corp. under contract to Marshall Space Flight Center (MFS-14882)

Circle 7 on Reader's Service Card.

CIRCULAR CAM WELDING HEAD

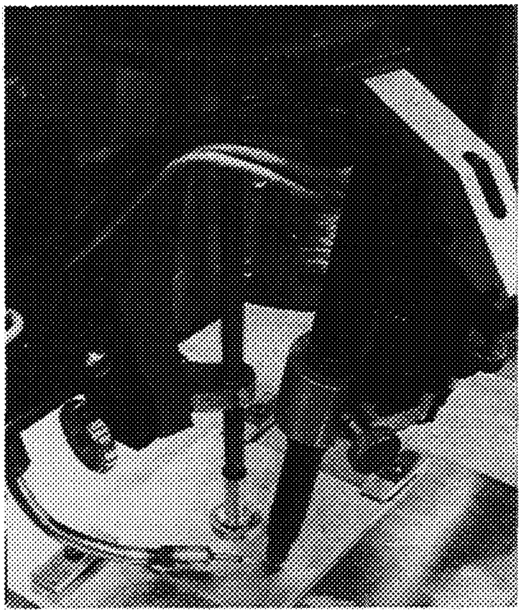


Figure 1

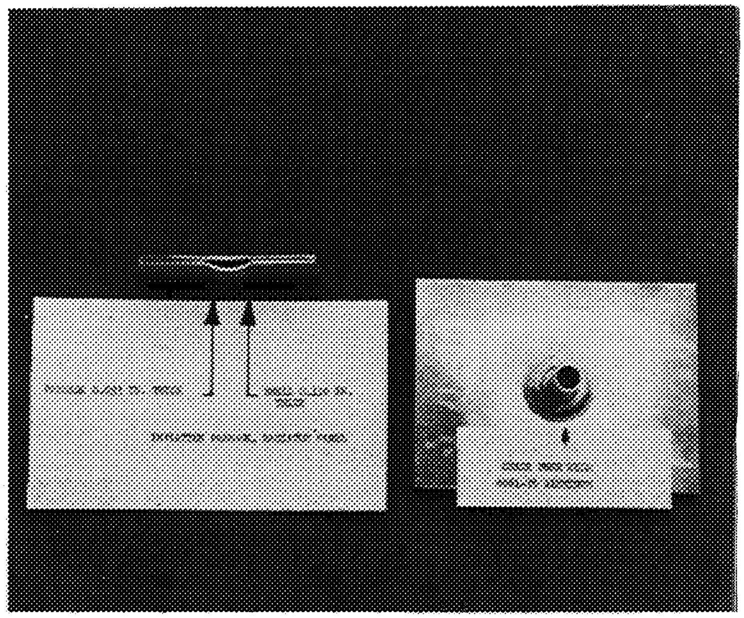


Figure 2

A new type of rotary welding head automatically makes circular welds in the range of 0.5 inch to 6 inches in diameter. Such welds are more uniform than those produced by manual welding and are better suited to special part configurations when using alloys.

This circular welding unit should be useful in increasing production capacity where closely controlled weld conditions are required, as in work on boilers, heat exchangers, and nuclear reactors.

The ac-driven circular cam welding head (Fig. 1) incorporates eight gear-driven adjustable cams that permit over-travel for current start-and-stop control on a full 360° circular weld. Compared with the usual manual operation, this device produces superior welds that are relatively free of distortion. The automatically controlled welding of varied cross sections or dissimilar materials would not be practical with manual techniques. If provided with X-Y-Z positioning, multiple tube headers for a variety of purposes could be produced at reasonable cost.

In conclusion, the basic circular cam technique of automated control need not be limited to tungsten-inert gas (TIG) welding. The quality of the welding is apparent in the flange at the right in Figure 2.

Source: Wilson W. Harrison of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15180)

No further documentation is available.

IN-PLACE WELDING HEAD FEATURES FIXED POWER SHOE

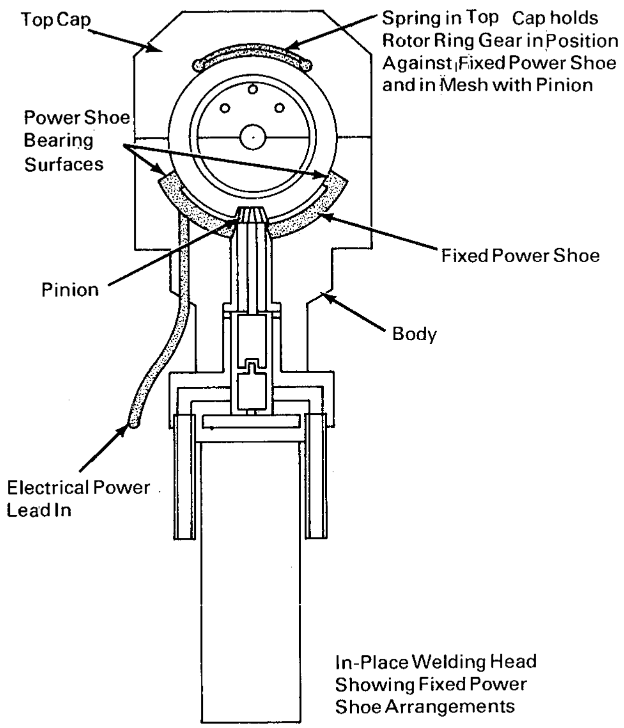
An in-place welding head with a fixed power shoe offers great promise in the diversified areas of industrial joining and bonding technology, and machine tools and fixtures. Because of increased reliability and efficiency, this device should find wide application. The earlier difficulty was to devise an improved means of transmitting electrical power to the rotor ring gear on existing in-place tube welding heads. Prior to this innovation, spring-loaded pins and shoes were used for power transmission to the rotor ring gear. This method proved unsatisfactory for a number of reasons, not the least of which was difficulty of repair and assembly.

The problem was solved by fixing the power shoe (see fig.) to the ring gear and keeping the latter in position with a flat spring. The welding head body is machined to accept a copper shoe secured by a screw-type lead pin. The rotor ring turns on two bearing surfaces machined in the shoe. The top cap houses the flat spring opposite the fixed shoe with the top cap installed. By exactly positioning the rotor ring gear, positive electrical contact is ensured with the shoe.

An important advantage of this innovation is its applicability to any automatic in-tube weld head of configuration similar to that described.

Source: E. J. R. Lang of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18082)

Circle 8 on Reader's Service Card.

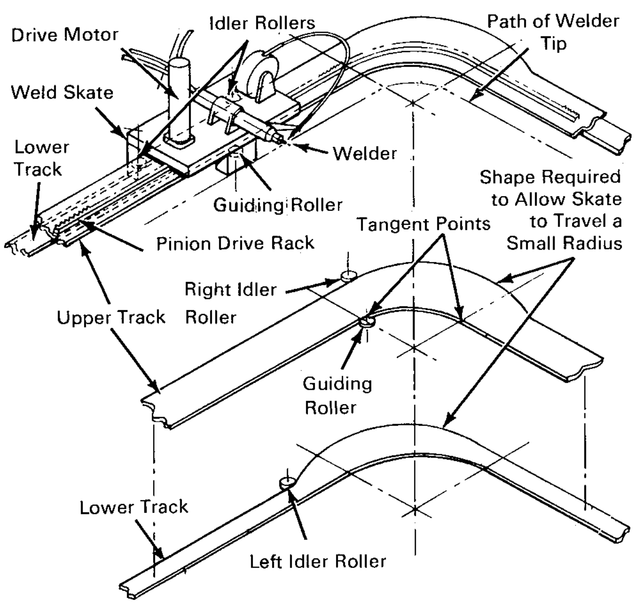


In-Place Welding Head Showing Fixed Power Shoe Arrangements

DUAL SKATE WELDER

The dual track skate welder is superior to the single track skate welder previously used.

Any manufacturer interested in the use of a powered skate for welding or trimming an assembly with sharp angles will benefit by this innovation. Its industrial applicability is, therefore, potentially wide.



When negotiating a sharp radius, the leading skate rollers formerly required a different shaped track than the trailing rollers. Even a spring loaded roller did not overcome this problem. The new method (see fig.) eliminates the spring roller problem. Two tracks are used. The upper track accurately guides the right idler roller and one outer guide roller. The second track guides the left idler roller. The use of a single inner roller requires no calculations. This idea is a marked improvement over previous welding methods requiring directional changes.

Source: Robert Dorsky of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14776)

Circle 9 on Reader's Service Card.

SPOT LOCATING DEVICE FOR MAKING OVERLAPPED SPOT RESISTANCE SEAM WELDS

This device is used to insure accurate location of spot welds prior to making seam welds. It is also used for making accurately spaced stitch welds. Since many industries have to meet continuous welding demands of all types, this device should

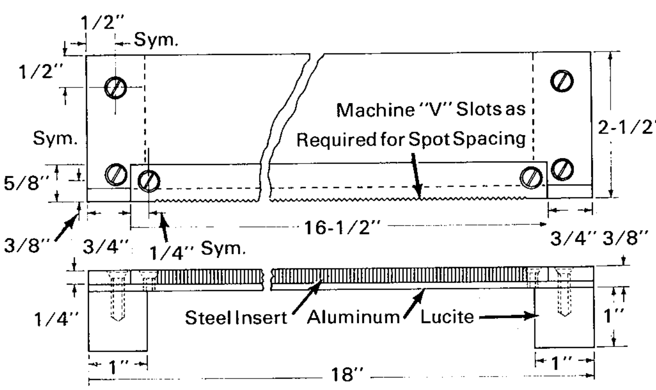


Figure 1. Spot Locating Device—Enables Accurately Overlapped Spotweld Location for Seam Weld by Spot Welder.

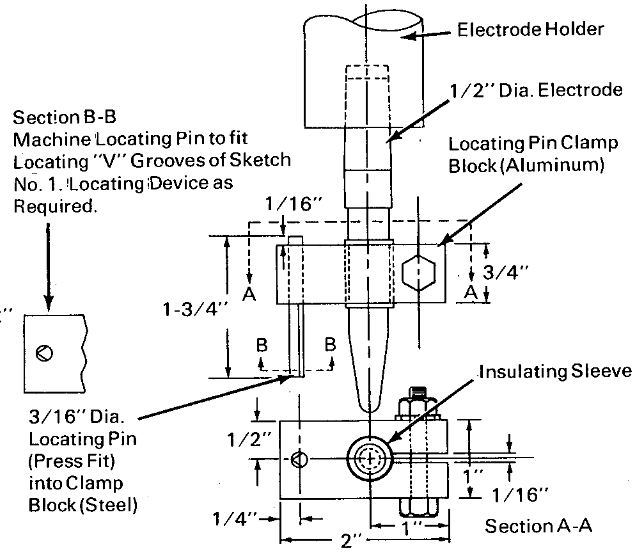


Figure 2. Locating Pin and Upper Electrode to be used with Spot Locating Device Illustrated in Figure 1.

find widespread use for adaptation of spot welding to the job of resistance seam welding.

Previously, the part to be welded was measured and spot-marked by hand. Then the part was placed between the electrodes and visually aligned with the marking. This was a slow procedure of moderate accuracy since specification requirements were very difficult to meet when they called for more than 50% overlap and leak-tight joints. The spot locating device features an aluminum fixture, with multiple "v" grooves, mounted on lucite blocks, as shown in Figure 1. The fixture is clamped to the parts to be welded. A locating pin is in turn clamped to, but insulated from, the upper spot welding electrode of a resistance spot welder, as shown in Figure 2. Parts to be seam-welded are placed between the upper and lower electrodes of the spot welder with the locating pin registered in the first "v" groove of the fixture. The parts and fixture are then indexed after each spot weld to the next "v" groove position in the locating pin until the seam weld is completed.

Parts are usually tack welded prior to the start of the seam welding operation.

Source: Donald F. Brace of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15262)

No further documentation is available.

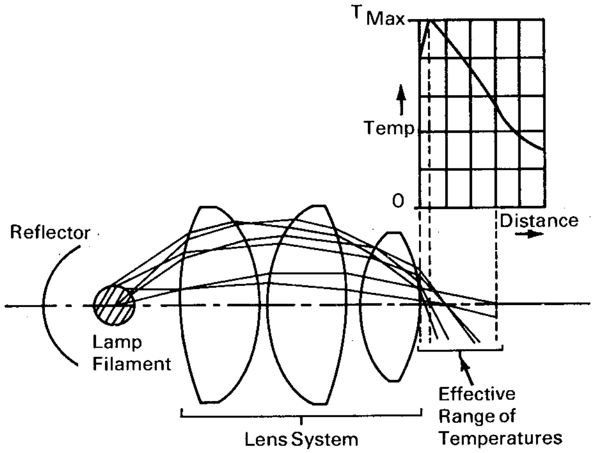
Section 3. Weld Monitoring by Radiographic and Optical Means

INFRARED BRAZING DEVICE

This innovation is an optical system designed with the heat-producing capability required for brazing and welding operations of a high order.

Efficient brazing, combined with low cost, is of critical importance to the continually growing microminiature circuitry technology.

The components for this device are arranged as follows: The reflector (see fig.) is positioned so that the image of the quartz iodine lamp filament



is focused back upon itself. The lens system projects the lamp filament and its reflected image approximately six millimeters in front of the last lens surface, thus producing a reduced image of the lamp filament. Optimum temperature for brazing and welding operations is reached approximately one millimeter in front of the last lens surface, as indicated on the temperature curve. An effective range of temperatures, as can be seen, is available, allowing compensation to be made for the varying materials used.

Source: J. F. Creedon and R. W. Kern of IBM Corp.
under contract to
Marshall Space Flight Center
(MFS-91481)

No further documentation is available.

CONTINUOUS RADIOGRAPHIC MONITORING OF WELDS

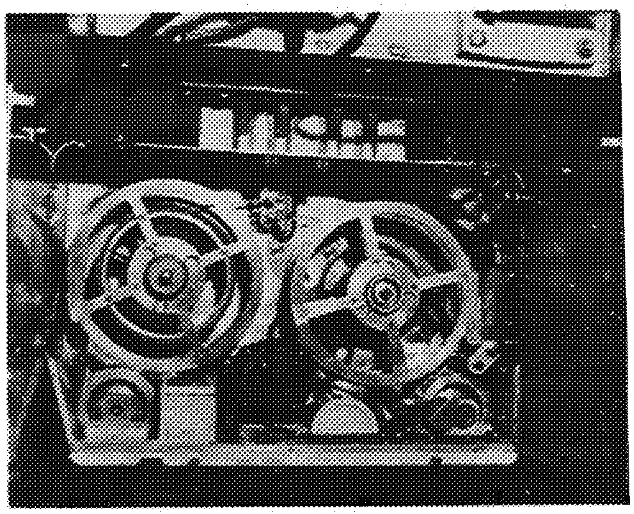


Figure 1

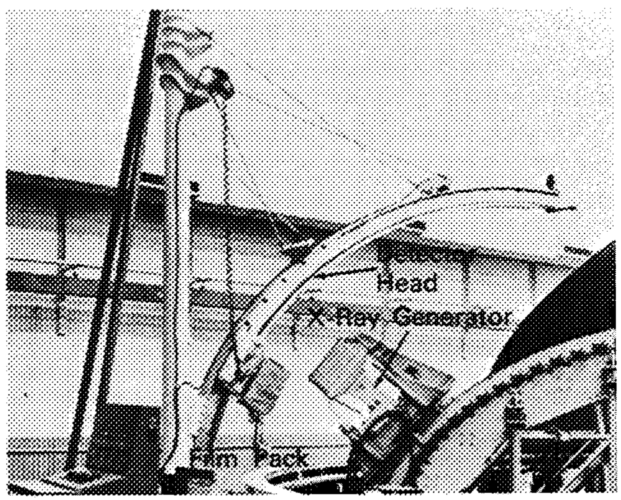


Figure 2

Accurate monitoring of weld operations produces more efficient results for all industrial requirements. Within the framework of detailed production scheduling, this system of radiography meets the needs of large components such as railroad tank cars, storage tanks and heavy industrial equipment. At the same time it uses commercially available basic equipment and maintains established criteria of radiographic precision.

A 200-foot length of 70-millimeter film is placed in a lead-covered film magazine, as illustrated in Figure 1. Motorized controls and switches advance the film approximately 16 inches at a time. Twelve inches of film are used for each exposure, leaving a margin of two inches at either end for overlap and to guard against double exposure. The X-ray film unit follows the external contour of the weld by riding a rack gear supported on a large curved beam, as shown in Figure 2. The beam can be swung into position from a vertical supporting member.

The X-ray machine is similarly driven on a contour rack which allows the X-ray to follow the inside contour. The workpiece is placed between the detector head and the X-ray generator. The X-ray tube shield is always placed tightly against the weld during exposure. This prevents radiation leakage. Before the X-ray shield is moved to the next position, the equipment has the capability of drawing this shield about four inches away from the inside surface. Interlock switches are provided for the entire X-ray equipment, preventing any exposures from being made unless the tube and X-ray film reel are correctly aligned and positioned against the weld.

Source: G. C. Occhipinti of
The Boeing Company
under contract to
Marshall Space Flight Center
(MFS-91806)

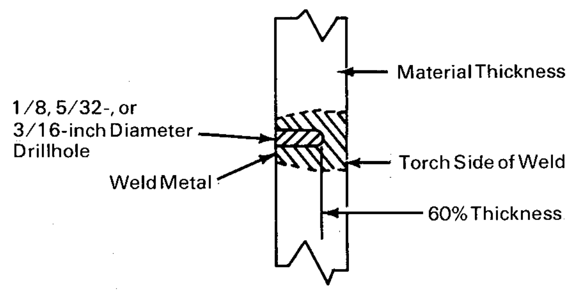
No further documentation is available.

Section 4. Specialized Welding

HOLE DRILLING TECHNIQUE FOR WELD REPAIR

This weld repair technique requires a minimum removal of metal. The basic method is one of drilling out localized internal and/or external weld defects in aluminum alloys. A minimum number of weld passes are then required to repair the drilled-out areas. In addition, the following benefits are realized: (1) increased metallurgical soundness; (2) fewer weld repair passes needed; (3) minimum resultant distortion of the assembly; (4) simplicity of procedure; and (5) repair reliability.

Any industry concerned with the welding of aluminum can therefore benefit from the use of this method.

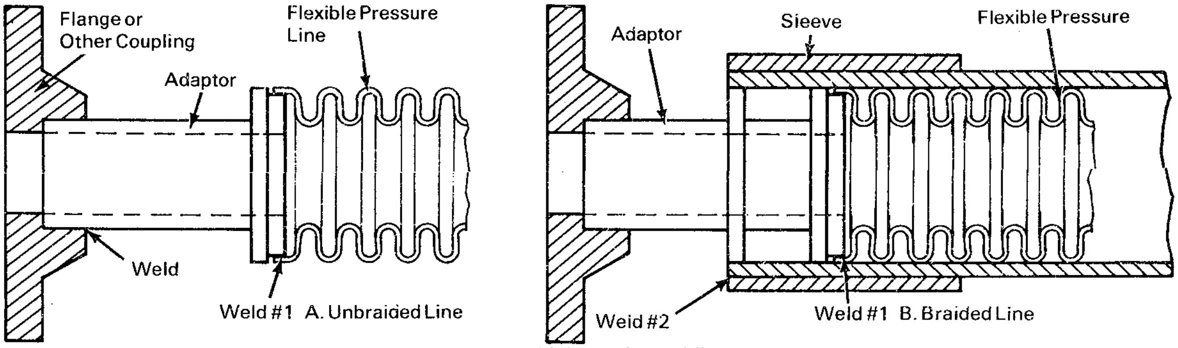


The innovation consists of using a hand drill to remove the damaged part of the repair, then making the new weld from the opposite side of the hole (see fig.). The work can be initiated from either side of the hole, though the repair itself is accomplished by heating the weld metal and placing it in the drilled hole. In tests of this technique, holes of up to 1/4-inch in diameter were first drilled in aluminum alloy (2014-T6) test panels. The holes were then gas-tungsten arc (GTA) welded, and the panels milled and inspected. Next, the holes were drilled along the root side of each weld to a depth of 60% of the panel thickness. These holes, with diameters from 1/8- to 1/4-inch, were then repair-welded and evaluated for quality. Favorable results with test drill holes up to 3/16-inch diameter demonstrated the validity of the drill-hole technique for the localized repair of internal weld defects. Repair-welded test panels were sectioned and machined to provide geometric tensile and bend test coupons. While results of the drill-hole repair technique are essentially favorable, care must be taken to ensure that the drop-through is aligned with the hole during welding. This is critical when formation of the underbead is being observed. With holes more than 3/16-inch in diameter, it may be necessary to run a remelt pass to obtain penetration and fusion of the drilled-out areas.

Source: Jack L. May of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-16392)

No further documentation is available.

WELDED FLEXLINE ADAPTERS



Flexline and Adaptor Assemblies

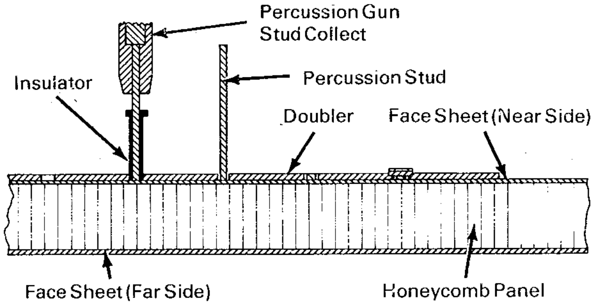
A new technique, in line with modern industrial requirements for welding flexline adaptors, can perform this operation while allowing a separate weld joint for braid (see fig.). This method has direct application in the highly complex and critical piping systems of today's nuclear reactors; in turbopump machinery and high vacuum feed-throughs; or where any durable and reliable assemblies are required. Results are superior to anything dependent on a silver-soldering procedure, while advantages include localized welding heat that does not affect the adaptor or flange, and an extremely durable weld under thermal or mechanical stress. Added strength derived from the sleeve used with the braided flexline is imparted to the adaptor joint. Where couplings (such as standard flanges) are conventionally silver-soldered to flexible stainless steel pressure lines, certain hazards develop. For instance, the heating required for the silver solder to flow into the "accordion" folds of a flexline generally oxidizes and distorts the face of the flange. This means added refinishing is required before use. Also, undesirable solder flow can permeate the inside of the flange, making total sealing difficult. Further, a silver-soldered joint can break down under temperature cycling when used with liquid nitrogen and other cryogenic fluids. It can also be broken by moderate radial loads on the flexline.

In the new process, the flange (or other coupling) is welded to the opposite end of the adaptor. To achieve this, the end of the flexline is cut at the narrowest point of an accordion fold. The adaptor collar is inserted in the flexline and the first weld completed against the collar shoulder. The pressure integrity of the adaptor flexline is tested before the flange is attached. For braided flexline, the line is cut off shorter than the braid, which is peeled back to expose the line for the first weld. The braid is then rolled forward and attached (with the sleeve) to a second collar on the adaptor for the second weld. The flange is welded to the other end of the adaptor.

Source: D. Wiley Jenkins
Goddard Space Flight Center
(GSC-10580)

Circle 10 on Reader's Service Card.

ALL-WELDED DOUBLER ATTACHMENT WITH PERCUSSION PINS



One of the most delicate problems in the welding industry—the repair of honeycomb panel structures—has now been solved by a welding method called the complete repair concept of doubler attachment. Heat input, which tends to damage the repaired work rather than restore design integrity, is reduced in this method to a minimum. This reduction is important when handling stressed face sheets.

A doubler (see fig.) is installed with anchor

Test Specimen Shear Values

Face Sheet*	0.008	0.020	0.030	0.040
Doubler *	0.020	0.020	0.030	0.040
Shear Value **	320	680	910	690
1/8" Dia Pins	290	770	780	910
and Breakaway	340	720	770	610
	300	900	750	520
	310	860	640	840

Face Sheet*	0.030	0.040	0.050
Doubler*	0.030	0.040	0.050
Shear Value**	1700	1750	1880
3/16" Dia Pins	800	1740	1660
and Breakaway	1250	1310	1650
	700	1500	1860
	1370	1720	1750

* Thickness in inches
** Shear value in pounds

percussion pins welded to the face sheet through drilled holes. The pins are then cut off flush with the doubler upper surface and breakaway percussion studs welded to pin ends and doubler. Both studs and fall caps have shanks for handling and assembly purposes. Each shank is later removed simply by breaking off. In the field, the main requirement is standard 110 V light duty percussion welding equipment.

A test specimen shear value table indicates that the percussion and breakaway pins and doubler attachment have passed tensile machine shear tests. Heat input is very minor and the resultant all-welded repair increases strength.

Source: Donald F. Brace of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-11797)

No further documentation is available.

METAL ARC AND GAS WELDING OF LOW CARBON AND LOW ALLOY, HIGH STRENGTH AND CORROSION RESISTANT STEELS

Table I
Shielding Gases

Gas	Description and Percentage		Procuring Agency Specification
Helium	Welding		MIL-P-27407
Argon	Welding Grade		MIL-A-18455
Argon	Liquid Source Purity 99.995 Min.		None
Argon-Oxygen Mixtures	99% Argon	1% Oxygen	
	98% Argon	2% Oxygen	
	97% Argon	3% Oxygen	
	96% Argon	4% Oxygen	
	95% Argon	5% Oxygen	

Technical requirements have been met for making welds of consistently high quality with low carbon and low alloy, high strength and corrosion resisting steels. In such areas as the construction of air frames, ships, pressure vessels, bridges and buildings, the new technique should prove valuable in critical, semicritical and even noncritical welds. Past attempts at this type of welding followed vague, obsolete, and inadequate guidelines, but the new specifications ensure high integrity of the welds.

A broad (summarized) review of the main sequence of operations and quality assurance provisions discloses the following: (a) easily applied

Table II
Allowable Defect Limits

	Class of Welding			
Defect	A–SP	A	B	C
1. Cracks	None	None	None	None
2. Mismatch	10%T or .06 in. [1]	10%T or .12 in. [1]	20%T or .18 in. [1]	20%T or .18 in. [1]
3. Porosity Open to Surface	None	1 per in. [2]	2 per in. .2 in. min. spacing [2]	4 per in. .2 in. min. spacing [2]
4. Undercut	None	10% or .03 in. 1T Max. Length [1]	10% or .05 in. 3T Max. Length [1]	20%T or .05 in. 5T Max. Length [1]
5. Incomplete Penetration	None [3]	20%T or .03 in. Depth 1 Max. Length	20%T or .05 in. Depth 2T Max. Length [1]	20%T or .05 in. Depth 4T Max. Length [1]
6. Cold Shut [3]	None	1T or .1 in. [1,4]	1T Max. Length [4]	2T Max. Length [4]
7. Overlap [3]	None	1T or .1 in. [1]	1T Max. Length	2T Max. Length
8. Concavity	None	20%T or .03 in Depth 1T Max. Length [1]	20%T or .05 in. Depth 1T Max. Length [1]	20%T or .09 in. Depth 1T Max. Length [1]
9. Craters	None	20%T or .03 in. Depth 1T Max. Length [1]	20%T or .05 in. Depth 1T Max. Length [1]	20%T or .09 in. Depth 2T Max. Length [1]
10. Underbead Drop Through	20%T or .04 in. For T Up to .25 in. and .07 in. For T≥.25 in. [1]	20%T or .04 in. For T Up to .25 in. and .07 in. For T≥.25 in. [1]	Clearance For Mating Parts	Clearance For Mating Parts

and uniform antispatter compounds are required; (b) all welds, unless otherwise specified, must be Class A and must conform to definite processes and heating requirements; (c) mismatch of fit must not exceed by more than 10% the breadth of the thinner member; (d) welding machines and operations must meet the standards of a competent inspector; (e) argon, helium or mixtures of the two must be used for the gas shield (see Table 1) and must flow from the welding electrode holder at a rate that will protect the weld from oxidation; (f) unless otherwise specified, preheating to between 150°F and 400°F is optional for the steels mentioned; (g) symmetrically placed tack welds may be used as required to hold the parts and ease subsequent welding; (h) all welded assemblies must be cleaned of oxide, flux, scale or other foreign matter and must meet required standards of "Allowable Defect Limits"; (i) if specified by drawings, penetrant, magnetic particle, and radiographic inspec-

Table II (Continued)
Allowable Defect Limits

Defect	Class of Welding			
	A–SP	A	B	C
11. Thinning	Not Less Than Min. T	Not Less Than Min. T	Not Less Than 80%T or 0.05 in. 3T Length 1	Not Less Than 80%T or 0.05 in. 5T Length 1
12. Accumulation of Defects 3 to 10 Inclusive	Not Applicable	10T Minimum Between Any 2 Defects	6T Minimum Between Any 2 Defects	4T Minimum Between Any 2 Defects
13. Subsurface Defects Such As Inclusions, Porosity, Incomplete Fusion 5	Maximum Dim. of Any Single Defect Shall Not Exceed 30% T or .1 in. Whichever is Lesser Accumulation Per Curve.	Maximum Dim. of Any Single Defect Shall Not Exceed 50% T or .15in. Whichever Lesser Accumulation Per Curve. 6,7	Maximum Dim. of Any Single Defect Shall Not Exceed 70% T or .2 in. Whichever is Lesser Accumulation Per Curve. 6,7	Not Applicable

1. Whichever is the lesser.
2. Maximum size 30 per cent of "T" or .10 inch, whichever is the lesser.
3. If these defects exhibit sharp radii, sharp terminations, or cracking, they shall be removed by grinding. If depression is not larger than permitted, they need not be rewelded.
4. Where possible by metal removal, depth of cold shut shall not cause joint thickness to be less than thinnest material being welded.
5. Any defect having a sharp termination or crack-like appearance shall be considered a crack. Two or more adjacent defects shall be treated as one when the space between them is less than the size of the smallest defect.
6. Aligned defects (4 or more) shall not be accepted when the spacing between them is less than three times the diameter of the smallest defect.
7. Aligned fine porosity is acceptable in ¼-inch length if less than ½-inch is composed of voids.

tion are mandatory; (j) weld defects (cracks, porosity, surface imperfection, inadequate joint penetration) may be corrected at the discretion of an inspector before assemblies leave the shop. Corrective welds must follow specifications required in the original weld; (k) visual inspection must include the use of a 10X magnifier where appropriate; (l) specific defects require Material Review Board Action; (m) for defect limits (subject to definitions) see Table II.

Source: John A. Richter of
The Boeing Company
under contract to
Kennedy Space Center
(KSC-10460)

Circle 11 on Reader's Service Card.

MODIFIED FUSE HOLDER FOR REMOTE HELIARC WELDING

The problem of placing tungsten-inert gas (TIG) welding equipment close to a job has been solved by a simple modification which permits TIG welding in remote areas without the need of moving welding machines.

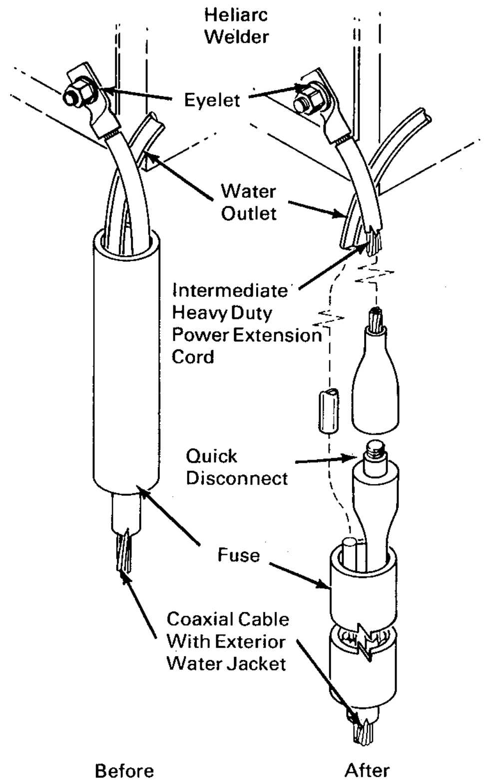
Formerly, a standard fuse holder eyelet was attached to a stud on the welding machine, which prevented the use of a power extension. This resulted in a waste of time and effort to get the equipment correctly positioned and also subjected it to needless hazards.

The improved efficiency resulting from the disclosed modification should prove useful in many commercial and industrial welding areas.

The standard fuse holder eyelet is replaced by a male quick-disconnect fitting (see fig.) that will accept power and water leads. Lead extensions may thus be installed between machine and fuse holder, thereby enabling welding to be performed remotely. The backup purge gas hose must also be extended by a similar length, or a purge gas bottle may be attached to the work site.

Source: Richard L. Smith of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18329)

No further documentation is available.



Section 5. Welding Preparation and Accessories

WELDING TECHNIQUE

A technique has been evolved for butt welding parts supported on wooden forms. Prior to the introduction of this technique, welding on wooden blocks created pockets in the weld due to gas buildup.

Any industry where heliarc welding is used in fabricating parts, but where wooden forms are still used, will benefit from this simple technique.

The innovation, which is considered a substantial improvement, still uses wooden forms, but these are now covered with stainless steel or copper. The retention of wood-based forms is cheaper than changing to other materials, and the metal coating effectively prevents gas pocket buildup.

The basic wooden form is fabricated and stainless steel or copper shim stock is placed between the form and the aluminum and steel parts. A heliarc head can then be run with proper penetration. Any gas generated by the heat will exit under the shim stock without contaminating the weld.

Source: R. V. Dover and T. D. Mullins of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-90502)

No further documentation is available.

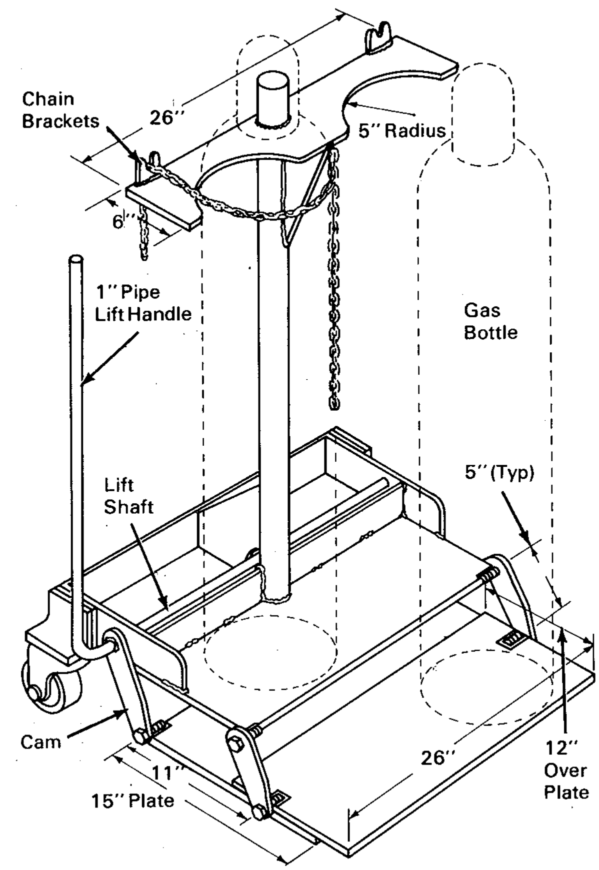
LIFTING DEVICE FOR GAS BOTTLES ON A PORTABLE WELDER

A simple procedure has been devised for lifting heavy gas bottles to the level of the stationary platform of a portable welding unit. The procedure uses a leverage principle to lift the bottles without strain.

Nationwide, throughout industry, thousands of cart-type portable welding units are in use. Heavy physical labor is required to load and unload, for example, 200-pound argon and helium bottles. This process alone not only involves risk of accidents and personal injury, but also results in a considerable waste of time and energy.

A one-inch pipe lift handle mounted on the cart (see fig.) operates a horizontal lift shaft, which in turn moves actuating cams. These cams raise to the required level the overlap plate with the gas bottle on it. The bottle is then "walked" or pushed a few inches into place on the rack and there chained. The lifting handle also is secured with a chain slipped into a notched cleat.

Source: Floyd Todd of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-91282)



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WELD PREPARATION FOR ALUMINUM BUTT WELDS

A recently developed method of weld preparation for aluminum butt welds eliminates the possibility of a defect such as lack of fusion. This

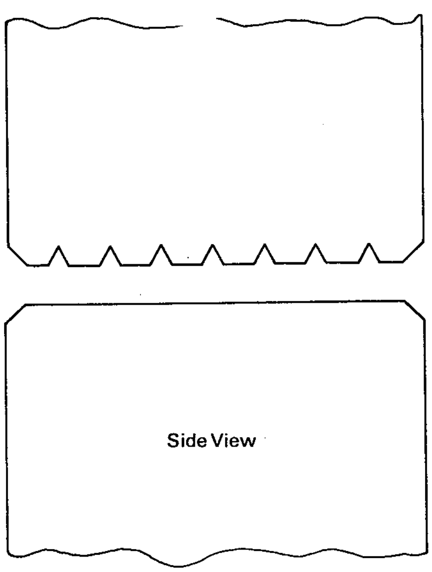

Fig. 1 Grooved Weld Preparation

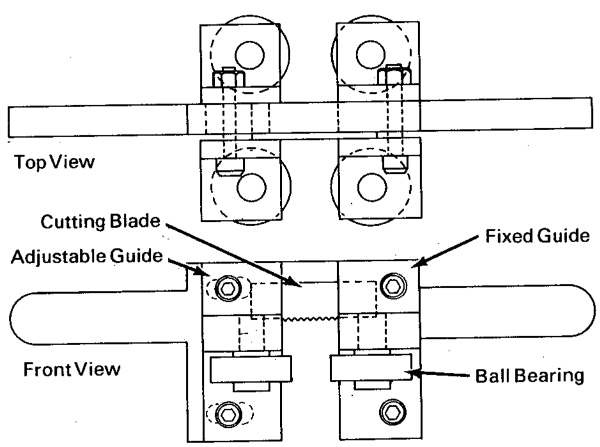

Fig. 2 Concept of Hand Grooving Tool

method makes it possible to locate poor fusion by increasing the magnitude of a potential void. Preparation consists of adding grooves to the face of a butt-joint weld. The grooves give a positive signal in the event of lack of fusion which would normally escape detection by nondestructive testing.

For example, in a pressure vessel, one of the faying surfaces of the vertical skin ring section weld is prepared with longitudinal grooves, approximately 1/4-inch deep. These grooves are spaced about 1/16 inch, center to center. Figure 1 shows grooved weld preparation, while Figure 2 depicts the concept of the manual grooving tool in some detail. To determine whether this grooving procedure might adversely affect weld quality, two sample panels, each 1/2-inch thick, cleaned and etched, were made up with double pass butt-welded seams. Half the weld area of the panel was grooved while the other half was left smooth. Radiographic and ultrasonic methods were used to inspect the welds, which proved to be of excellent quality.

This method also detects areas where penetration is lacking in double-pass butt welds.

Source: Drury K. Mitchell of
The Boeing Company
under contract to
Marshall Space Flight Center
(MFS-14751)

Circle 13 on Reader's Service Card.